HRPPD ageing digitizer data

M. Osipenko, J. Agarwala, F. Tessarotto et al.
INFN sez. di Genova and Trieste

HRPPD meeting, 21 Aprile 2026

Digitizer data from ageing measurements

Proposed measurements:

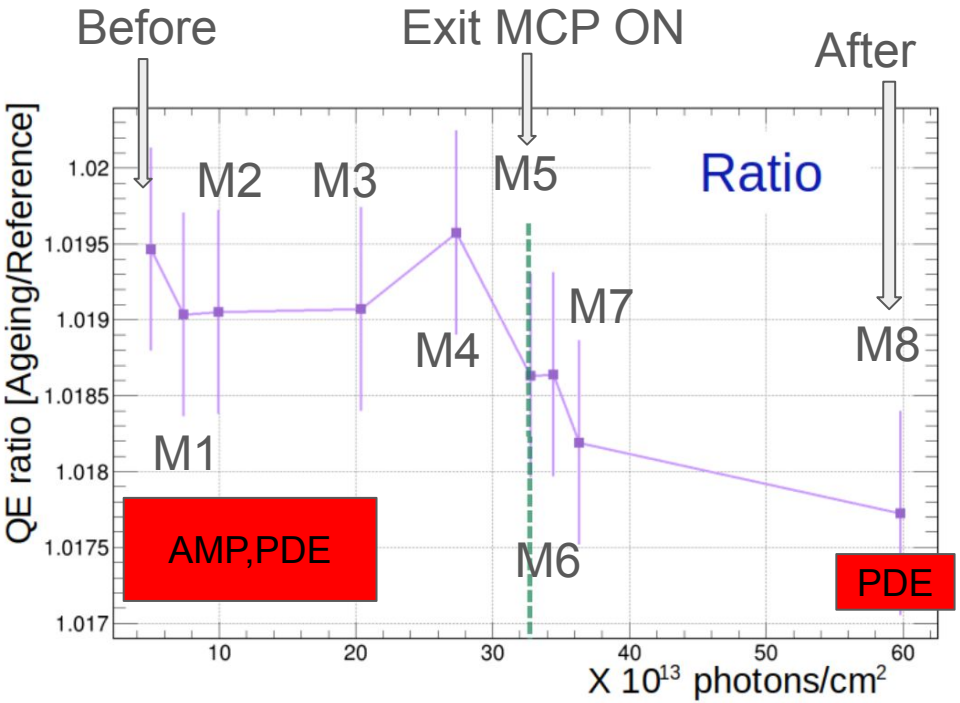
1. AMP = pure SPE measuremtens with λ=0.01, only in pad centers;
2. PDE = high stat. SPE measurement with λ=0.20, smaller steps of 0.5 mm (pad=3.25 mm);
3. ~~AfterPulse measurements at λ=3.~~

Actually measured only first two, and not for all the steps of ageing.

Five optics configurations (405 nm)	
Picoquant Pulsed Laser	Continuous LED
~1% SPE (λ=0.01), OD2 **measurements**	Fibre direct **QE** LED I_{SET} = 300 mA
~20% SPE (λ=0.2), OD1 **measurements**	Fibre via 1 **AGEING** LED I_{SET} = 85 mA
~3 PE (λ=3) **measurements**	

Ageing steps

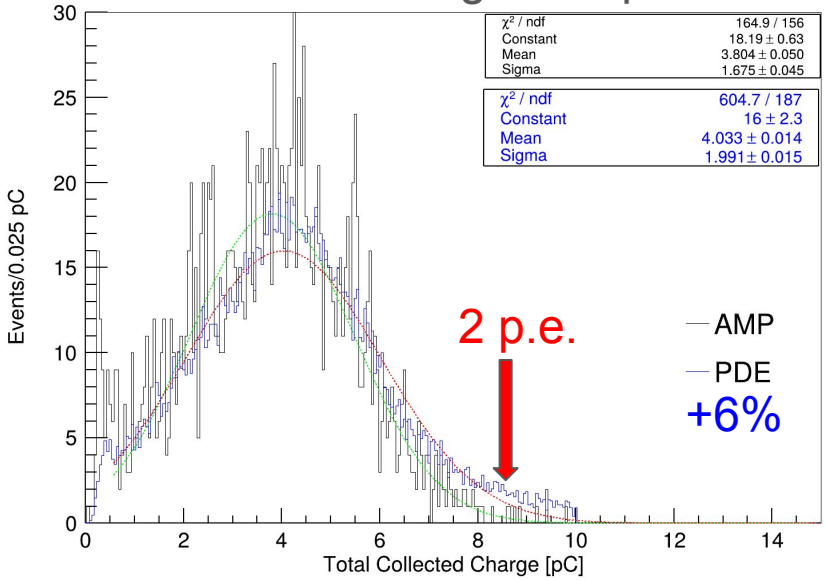
- AMP data contain only: Before, M1-M3;
- PDE data contain: Before, M1-M3 and M8:
  - Before -H1,H2,V1,V2/30 points (0.5 mm),
  - M1 - H1?,H2,V1,V2/15 points(1 mm),
  - M2 - H1,H2,V1,V2/30 points (0.5 mm),
  - M3 - H1/4 points?, H2,V1,V2/30 points (0.5 mm),
  - M8 - H1/4 points?, H2,V1?,V2/30 points (0.5 mm),
  - M8Oct - H1,V1/30 points.
- no digitizer data in M4-M7.
- Ref. A1T region has also M4 data (what was the purpose of these?)



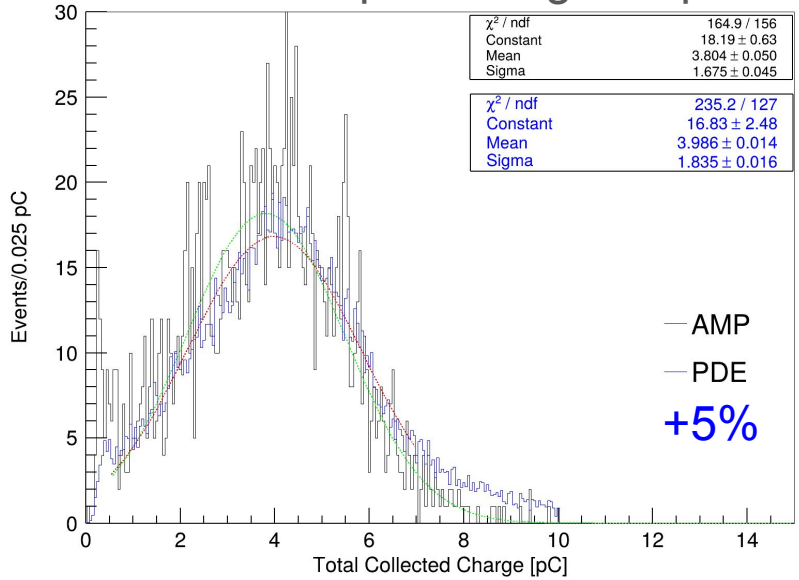
Difference AMP-PDE

- fitting entire spectrum with Polya+Exp. PDE data shows +6% gain;
- fitting entire spectrum with Polya+Exp. PDE data shows +5% gain;
- PDE data gives gain offset by +5%, but have 16 times larger statistics providing 4 times smaller error on the gain, but AMP data error on the gain is already 1.3% (4 times less than systematic offset of PDE data fit).

fit of entire range <15 pC



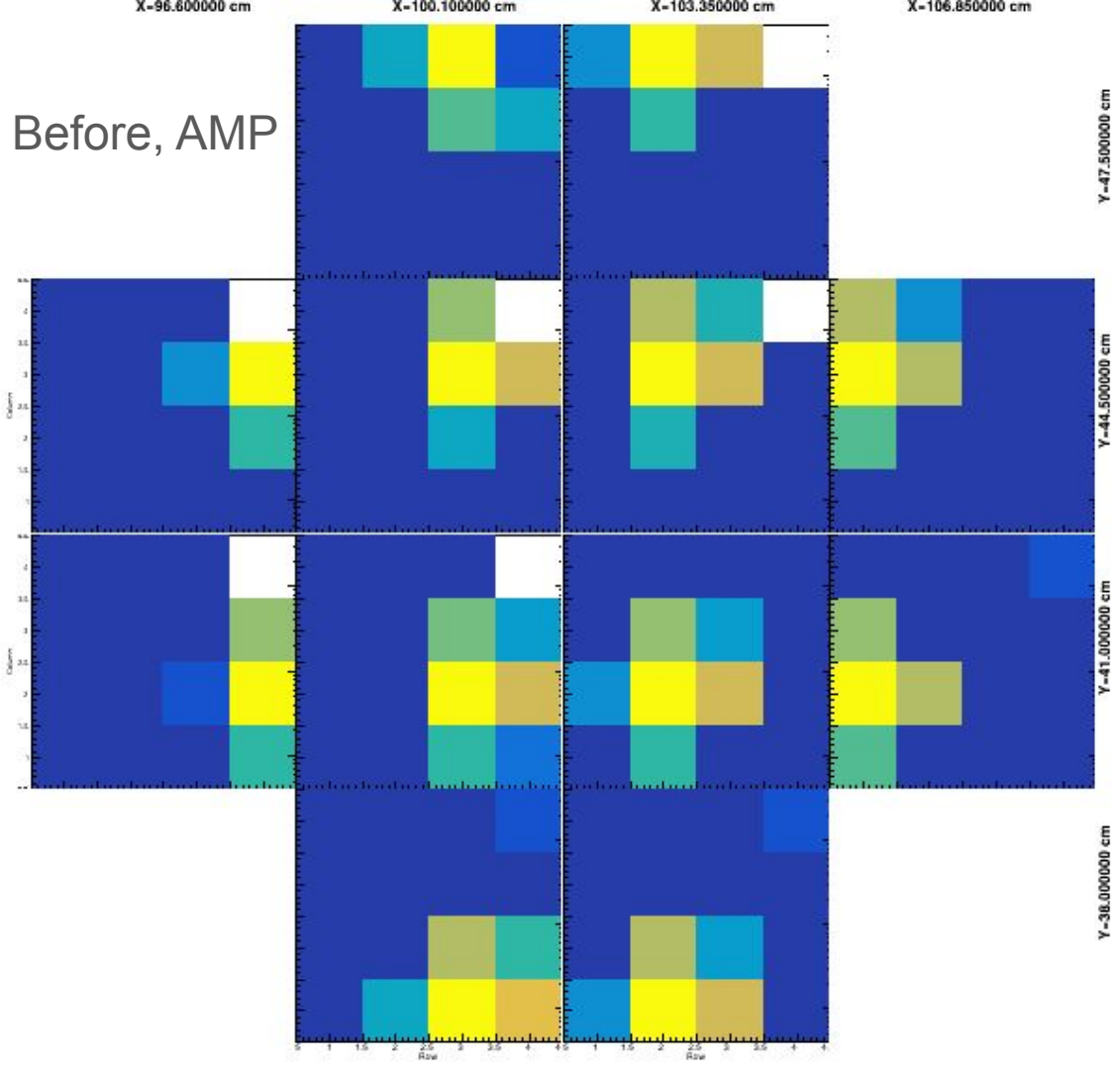
fit of SPE peak range <7 pC



Anode charge spot

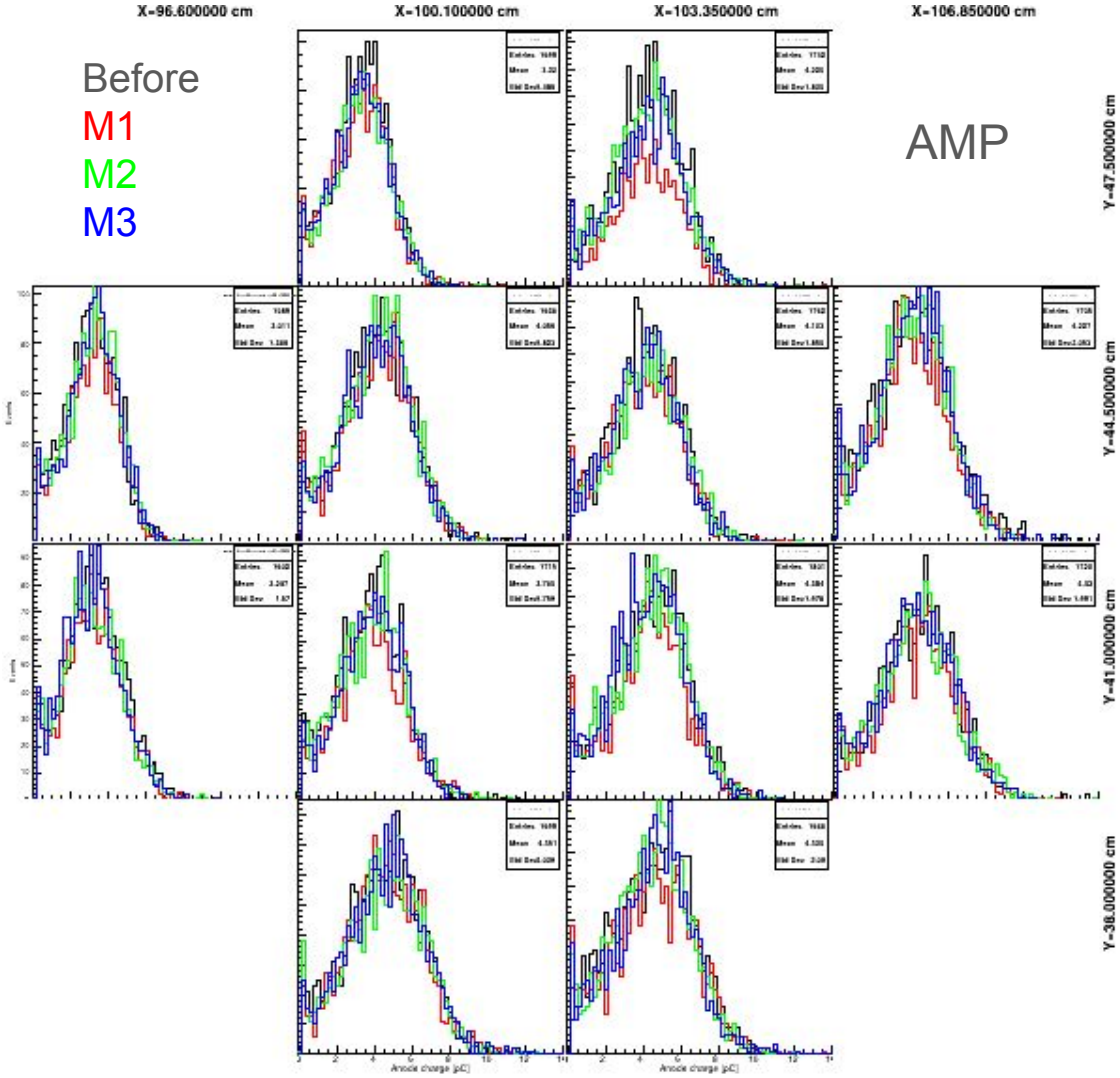
- spot has a halo of <20% in neighboring pads;
- halo is not symmetric in X ((laser is not set exactly to the center of the pad);
  - X: left 0.7%, right 17%
  - Y: bottom 3%, top 6%
- for the present scan span:
  - X: 14.5 cm/4.5 pads
  - Y: 14.5 cm/4.5 pads

to preserve the complete anode charge also at the borders, it would be useful to add one more pad at each border: 6x6=36 pads-4 corner pads.



Anode charge spectra

- no significant gain variations in the first 3 measurements with the Exit MCP OFF;
- differences <1-3% and comparamble to stat.err.;
- When Exit MCP is not used during ageing, gain remains stable;



H and V-scans of PDE

- Scans of PDE in step of 0.5 mm/1 mm, total span 14.5 mm in both directions - compare to the LED ageing spot=10.6 mm+3.5 mm of avalanche diameter at anode;
- Pulsed laser; focused spot (< 1mm);
- λ~0.2 (~ 20% non empty events);
- used 16 channels of V1742 digitizer, each run 100k events.

Ageing Region (D1B)

Y [mm]				
47.25	8 0	7 1	13 2	14 14
44.50	18 4	17 5	20 6	19 7
41.00	22 8	21 9	24 10	23 11
37.50	32 12	31 13	29 3	30 15
X [mm]	106.85	103.35	100.10	96.60

H1 H2 V1 V2

Pads
Digitizer channel

Reference Region (A1T)

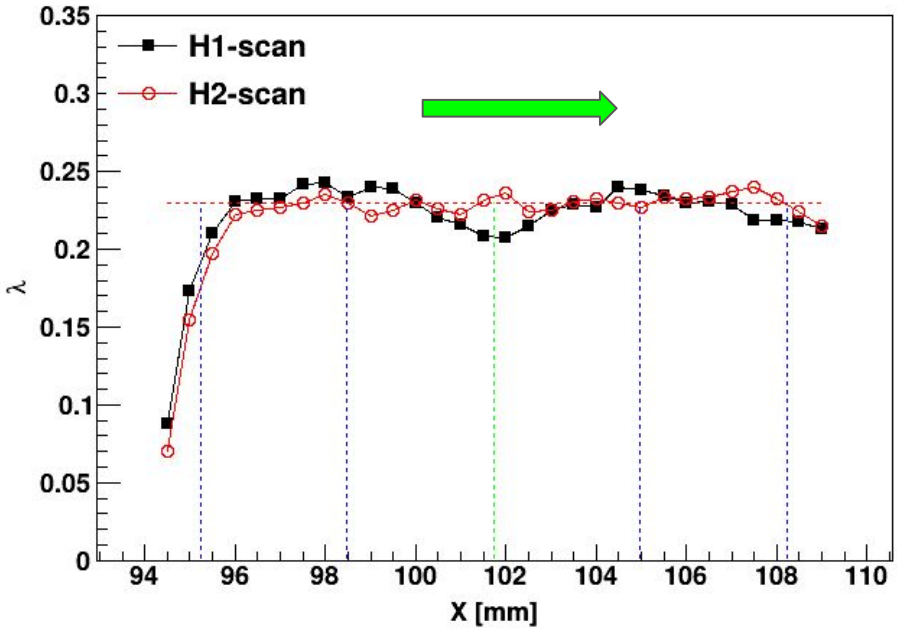
Y [mm]				
47.25	33 0	29 1	31 2	32 3
44.50	23 4	24 5	21 6	22 7
41.00	19 8	20 9	17 10	18 11
38.00	14 14	13 13	7 12	8 15
X [mm]	42.50	38.60	35.10	32.00

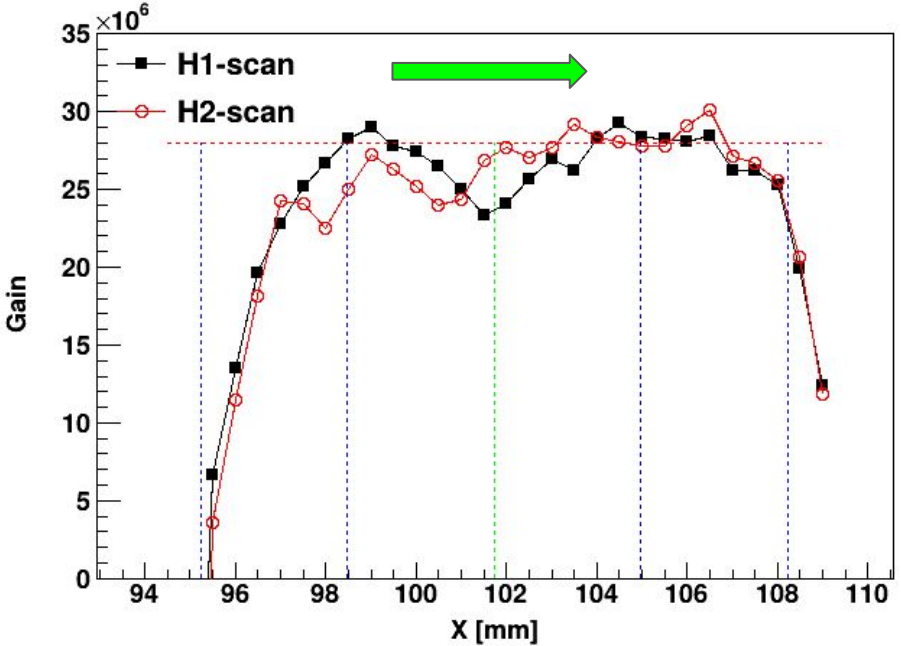
H1 H2 V1 V2

Pads
Digitizer channel

H-scans of PDE - before

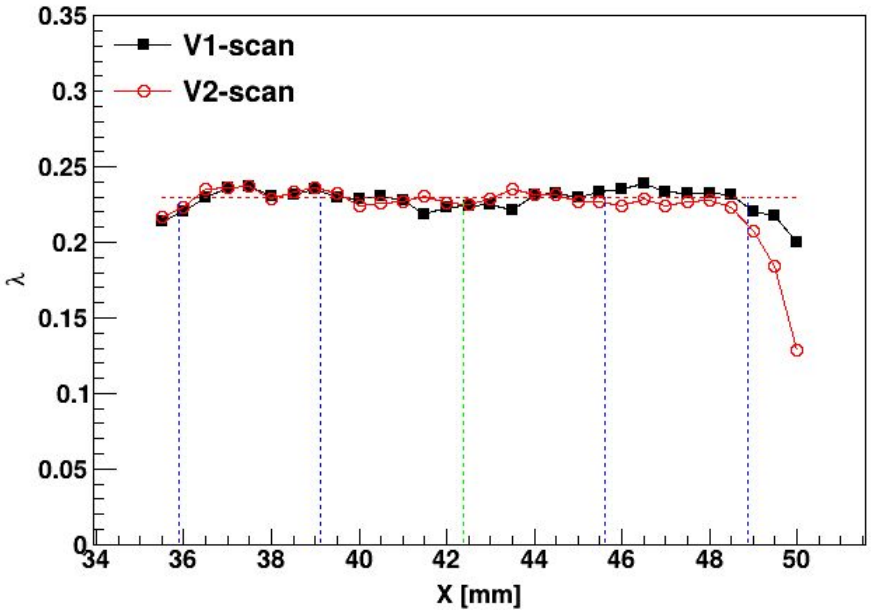
- PDE seems to be very non-uniform, variations up to 10%;
- PDE is not directly correlated with Gain (compare at X=98 and X=102 mm);
- Gain is also very non-uniform, variations up to 20%;
- center is offset in X by a few mm.

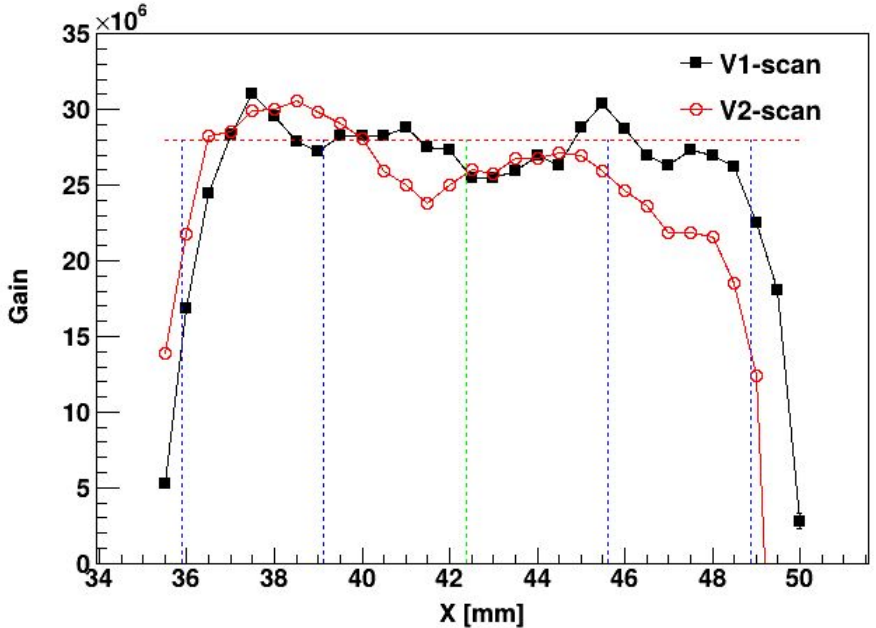




V-scans of PDE - before

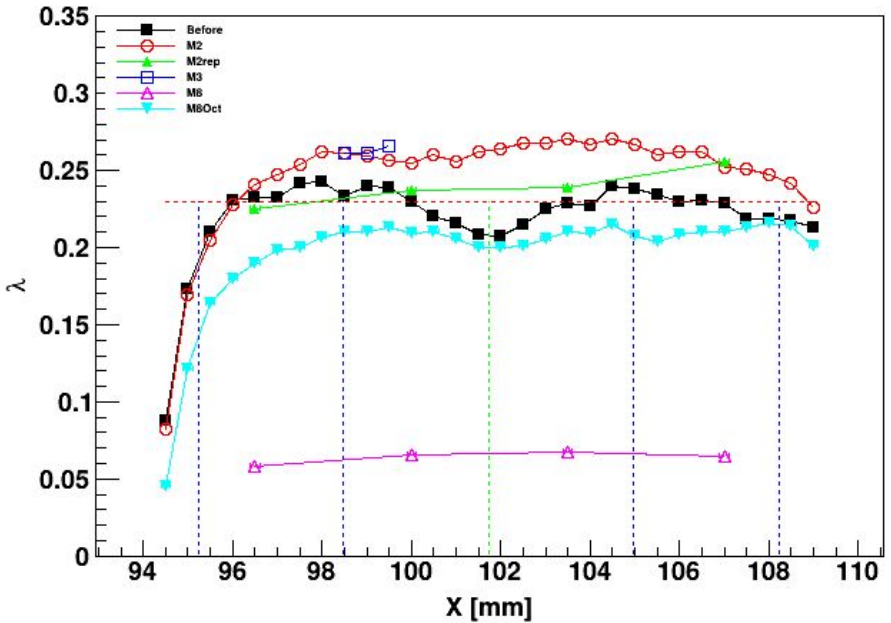
- PDE seems to be non-uniform, variations up to 5%;
- PDE is not directly correlated with Gain (compare at X=41.5 mm);
- Gain is also non-uniform, variations up to 10%.

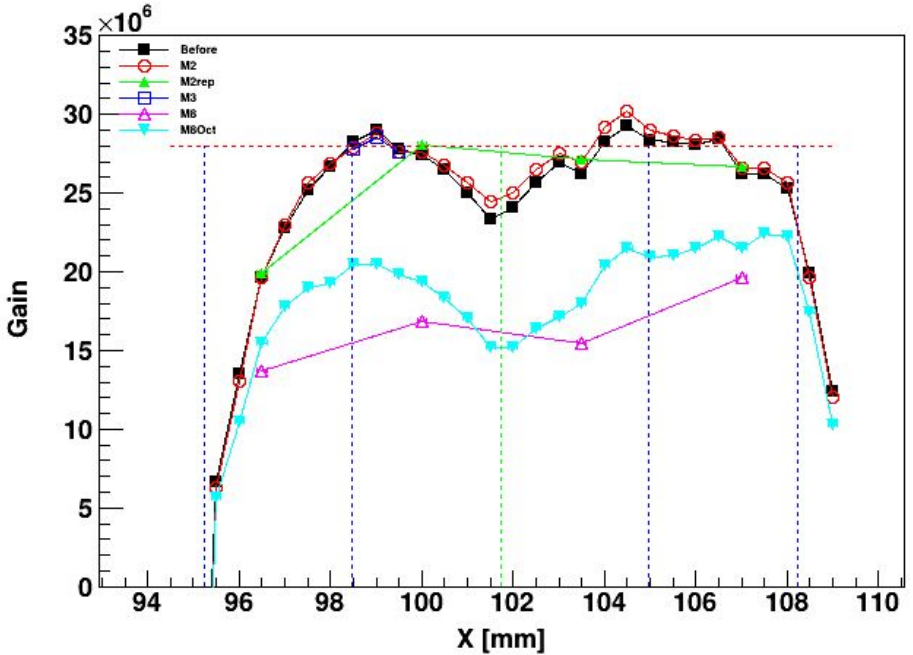




H1-scans of PDE - all

- absolute value of PDE is not reliable step-to-step - in M2+M3 it is 20% larger than Before;
- Gain instead is very reliable;
- M8=After is strongly depleted in both: gain (-40%) and PDE (-70%), but in October M8Oct recovered?

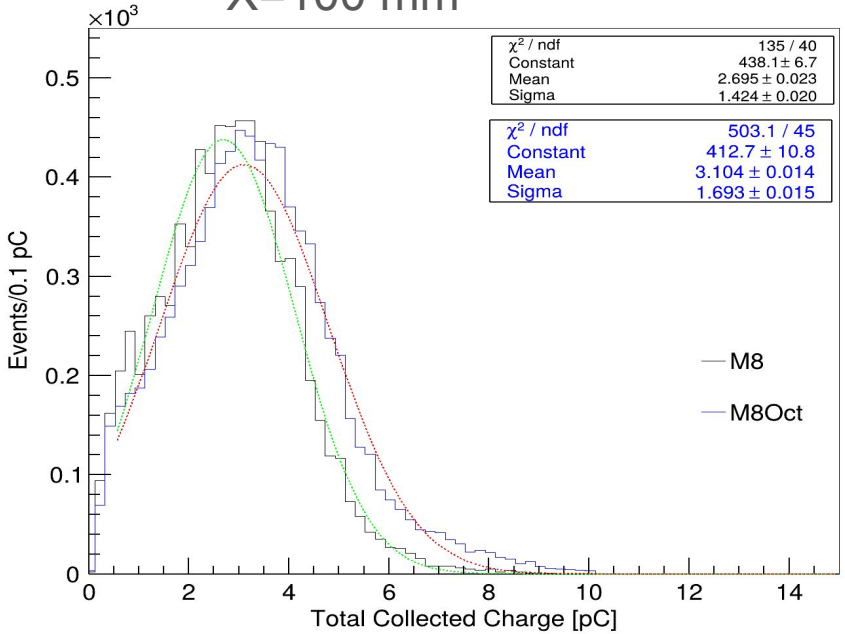




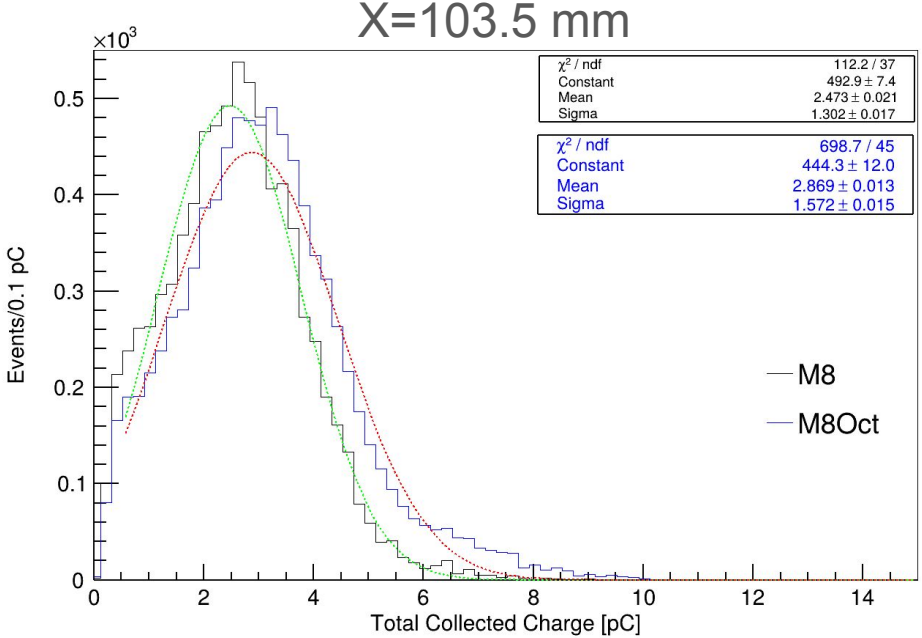
H1-scans of PDE - M8 vs M8Oct

- in M8Oct gain is higher by +16% w.r.t. M8, why?
- however, λ in M8 is clearly lower (no 2 p.e. peak), thus expected a positive offset of the fitted SPE peak of +6%;
- thus, presumable recovery of the gain in one month is +10%.

X=100 mm

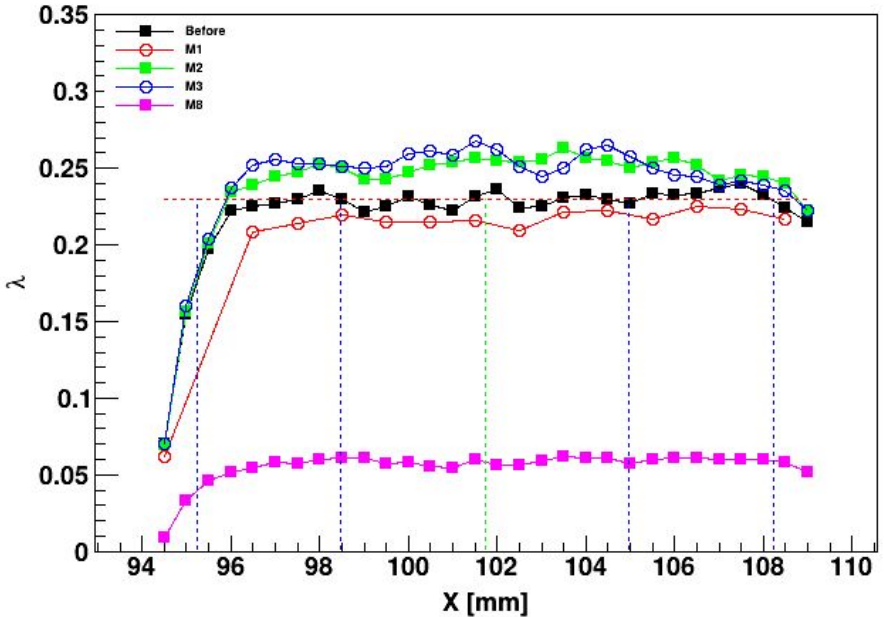


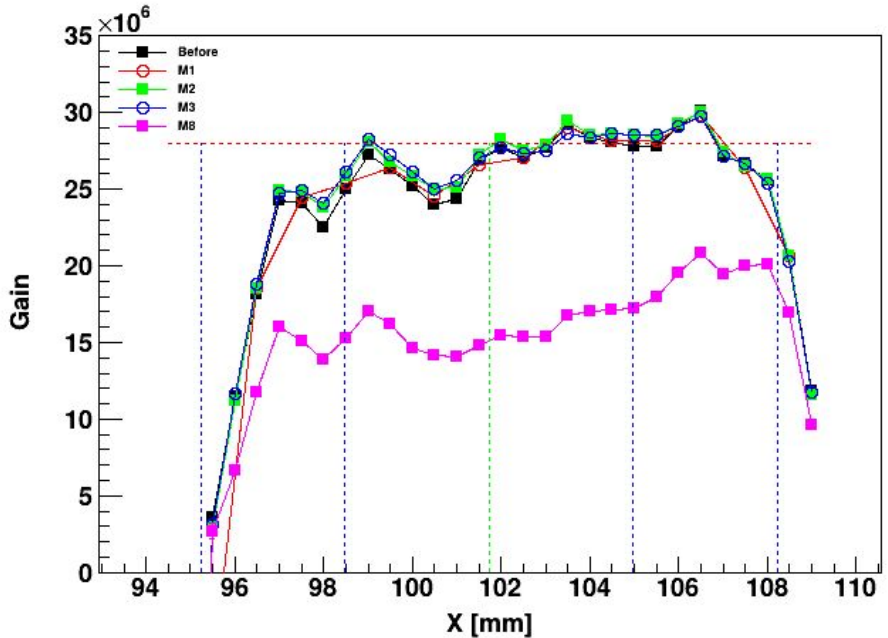
X=103.5 mm



H2-scans of PDE - all

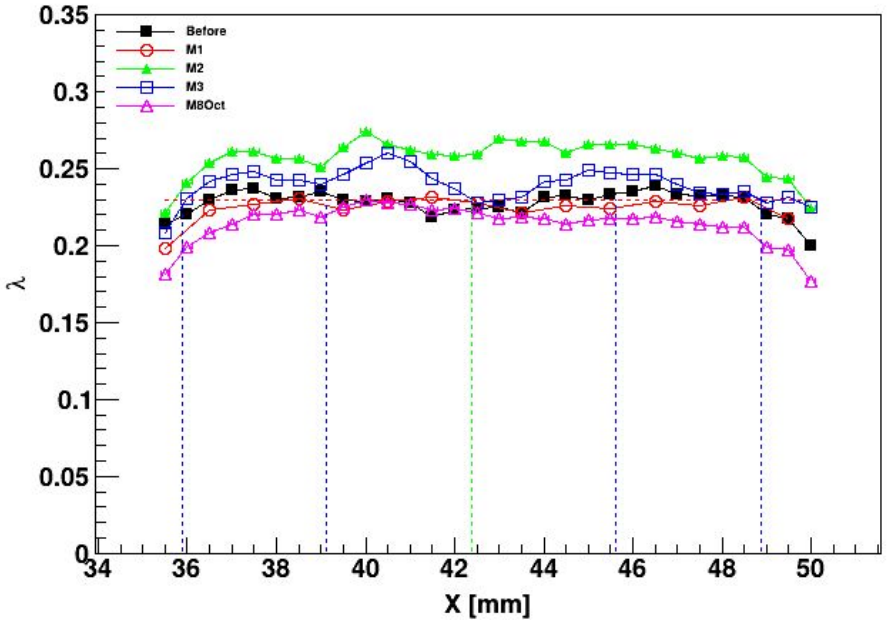
- absolute value of PDE is not reliable step-to-step, mean deviation =5.4% (6.3 σ);
- clear scale offset - presumably laser intensity settings were slightly different;
- Gain instead is very reliable, mean deviation =0.4% (0.9 σ);
- M8=After is strongly depleted in both: gain (-40%) and PDE (-70%), laser intensity probably was wrong.

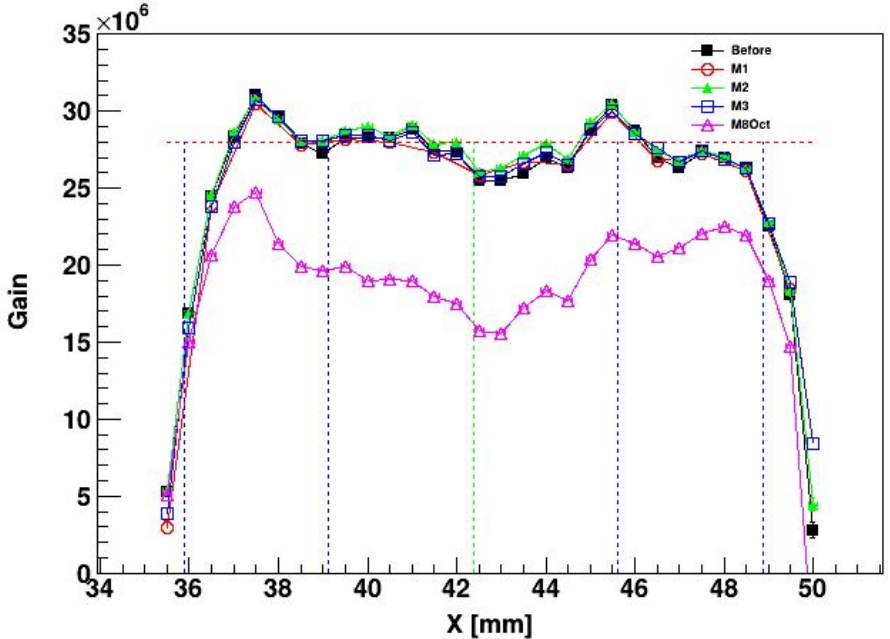




V1-scans of PDE - all

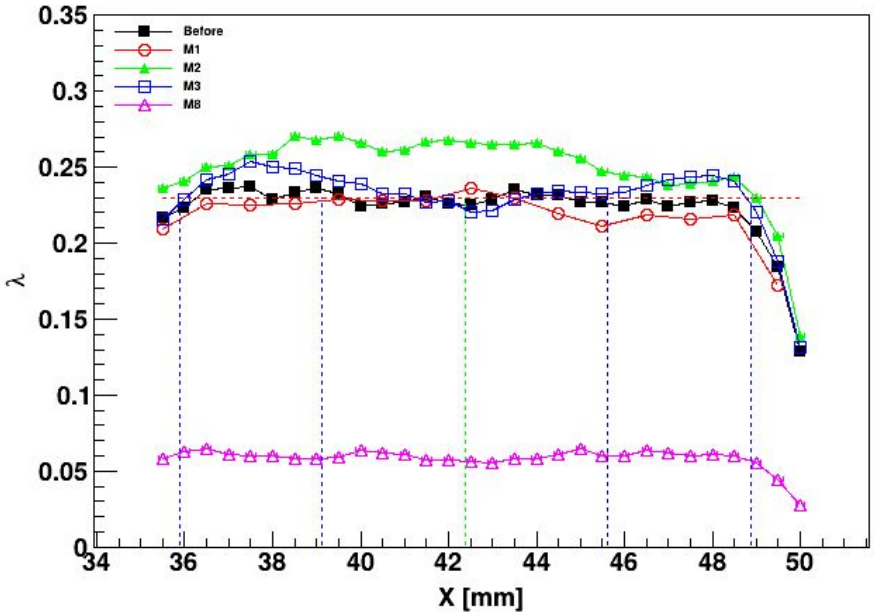
- absolute value of PDE is not reliable step-to-step, mean deviation M1-Before =1.3% (1.6 σ), deviations in M2 and M3 are much larger and X-dependent?;
- Gain instead is very reliable, mean deviation =0.2% (0.4 σ);
- M8Oct=After is strongly depleted in gain (-40%), PDE is unclear due to overall scale uncertainty.

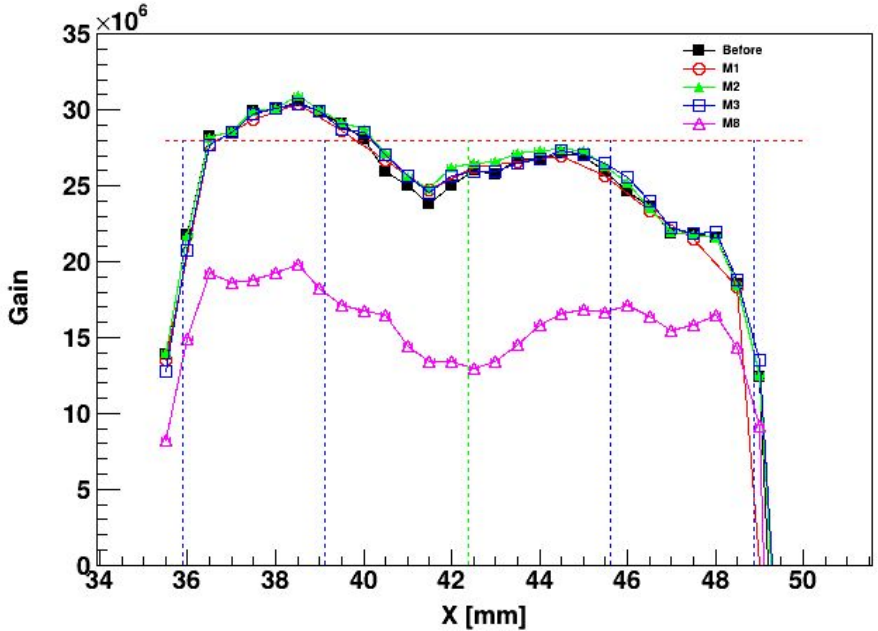




V2-scans of PDE - all

- absolute value of PDE is not reliable step-to-step, mean deviation M1-Before =2.8% (3.4 σ), deviations in M2 and M3 are much larger and X-dependent?;
- Gain instead is very reliable, mean deviation =0.5% (0.7 σ);
- M8=After is strongly depleted in both: gain (-40%) and PDE (-70%), laser intensity probably was wrong.

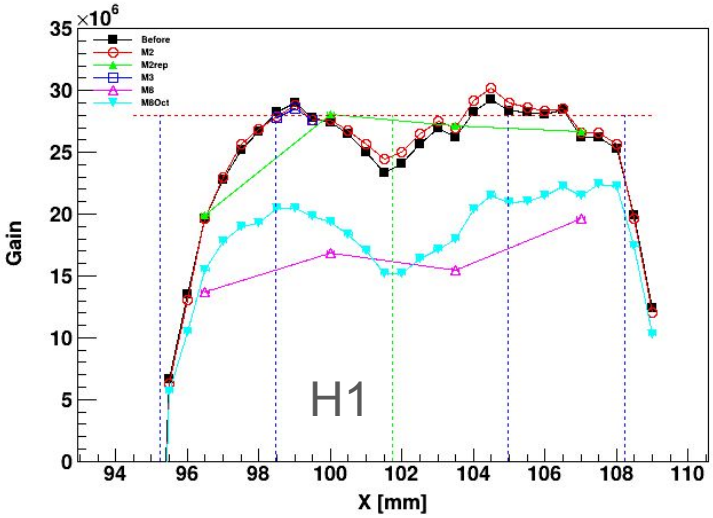


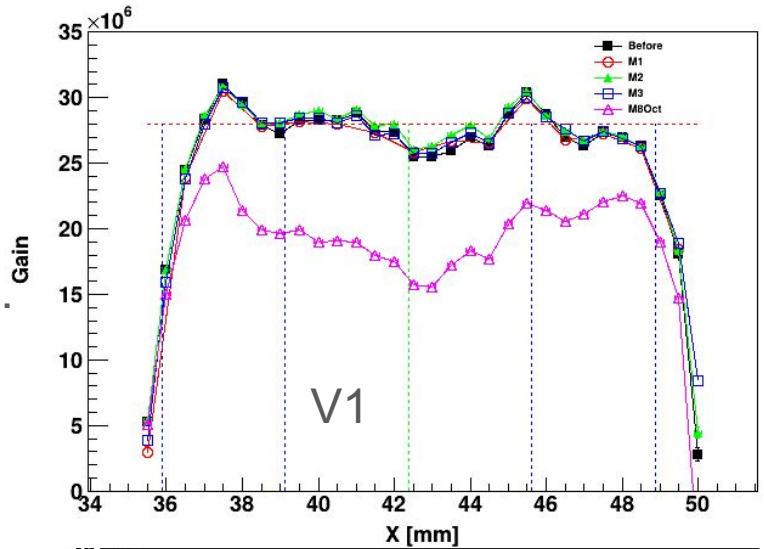


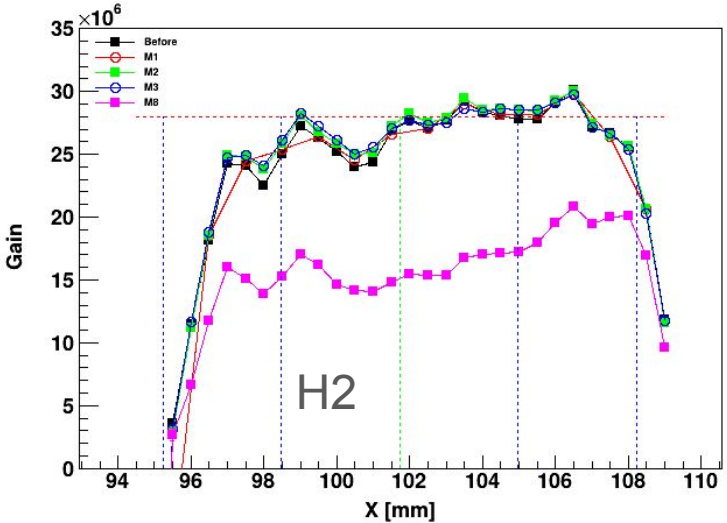
Gain

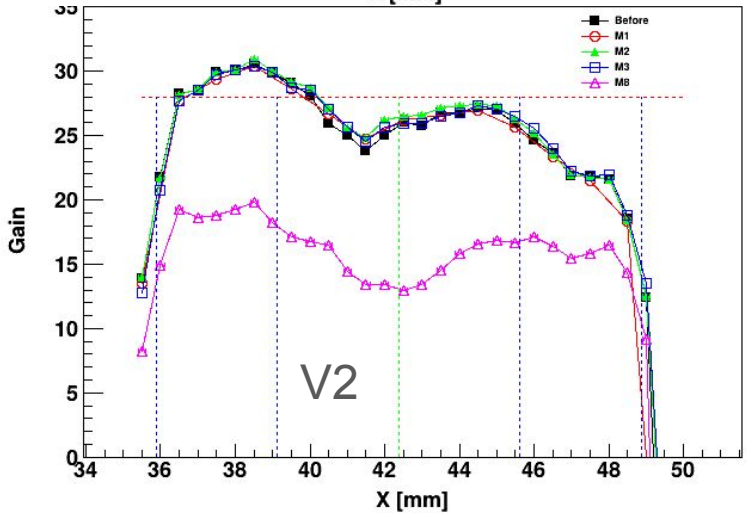
1) Gain drops on 40% after all irradiations.

2) shapes of the two scans in both H&V do not agree.







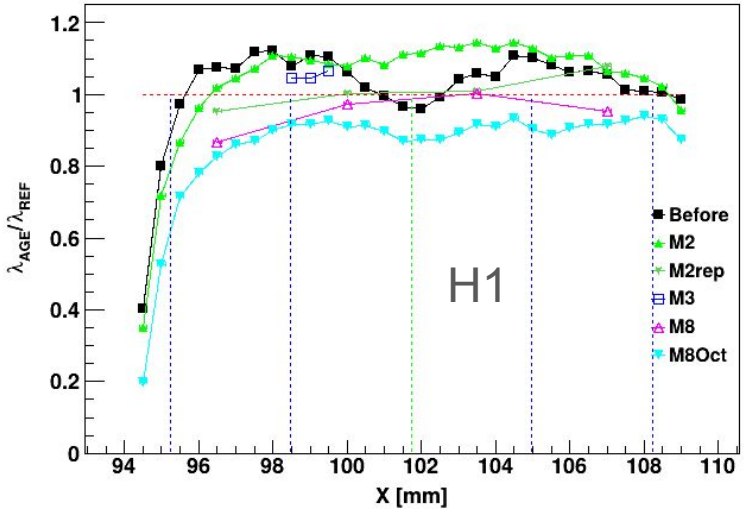


Relative PDE definition

- reference points are arbitrary - must give overall photon flux * PDE scale;
- but we have no setting points present in all measurements!
- take H2 as most stable: in central region X=34, 36, 38, 40 mm;
- for M8oct took ratio of M8/M8oct in H1 points X=32, 35.5, 39, 42.5 mm;

	H1	H2	V1	V2
Before	×	every 0.5 mm	every 0.5 mm	every 0.5 mm
M1	every 2 mm	every 2 mm	every 2 mm	every 2 mm
M2	every 1 mm	every 1 mm	every 1 mm	every 1 mm
M3	every 0.5 mm	every 0.5 mm	every 0.5 mm	every 0.5 mm
M8	4 points	every 0.5 mm	×	every 0.5 mm
M8oct	every 0.5 mm	×	every 0.5 mm	×

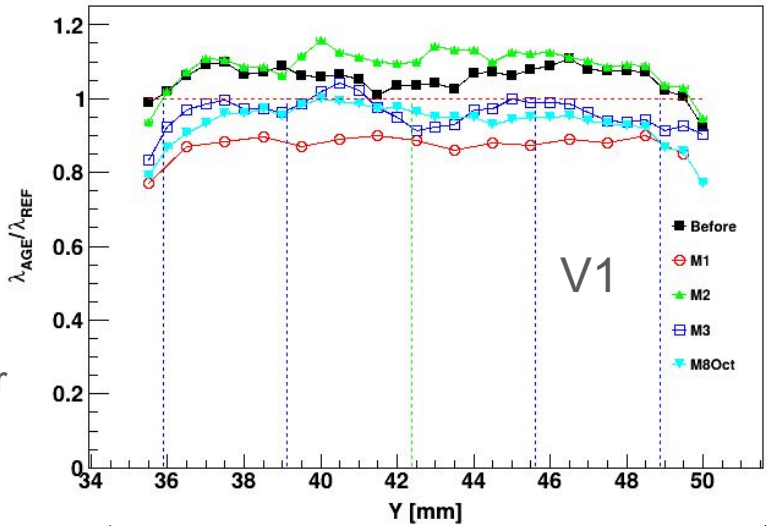
PDE

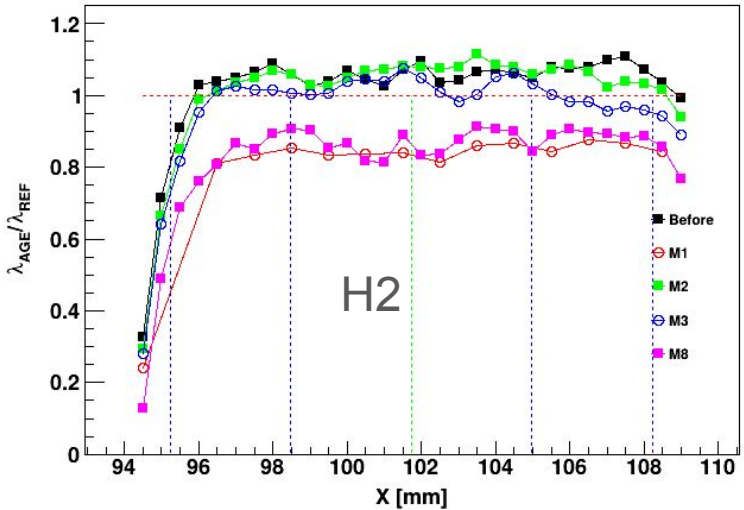


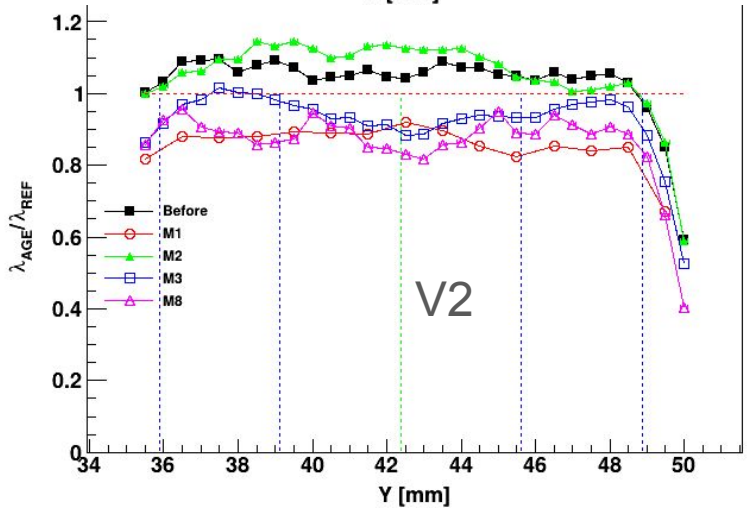
1) normalization of measurements are too scattered;

2) M8 and M8oct sometimes higher than initial measurements;

3) normalization stability must be improved!

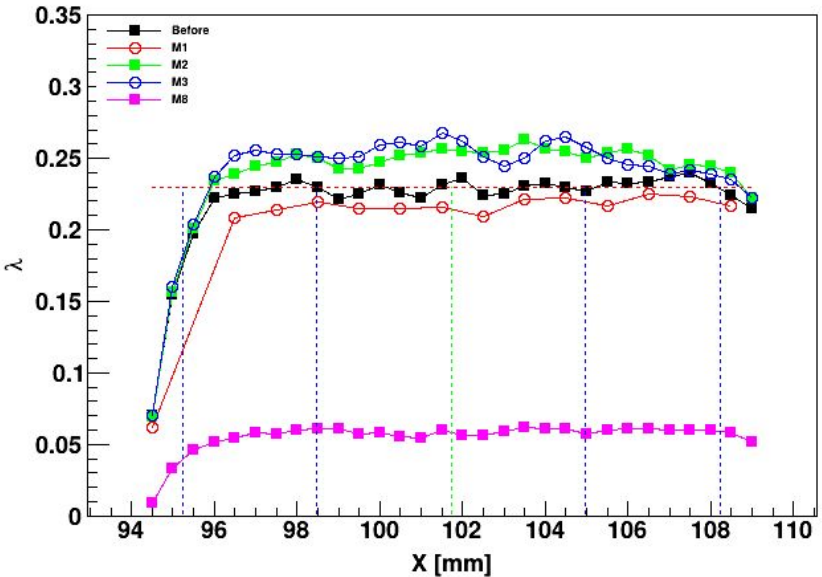


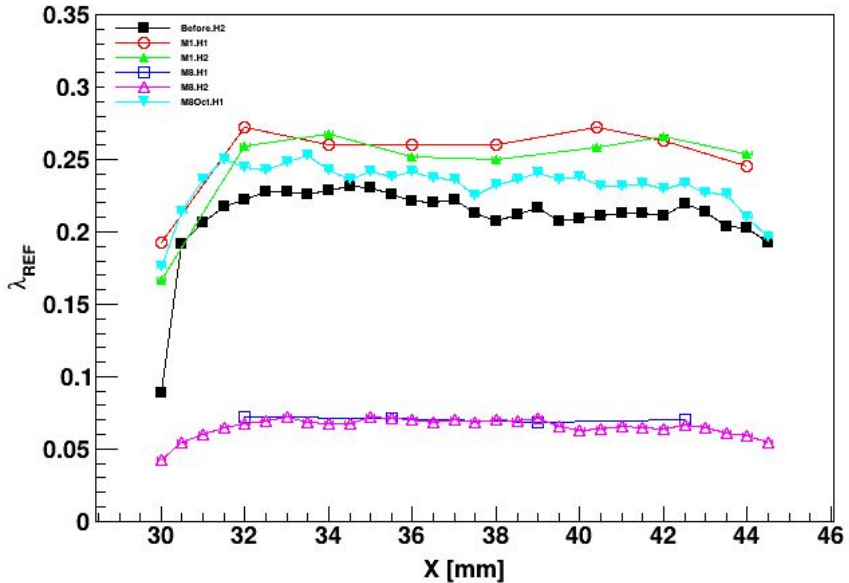




Relative PDE definition

- how to determine reference value of λ? Should it depend on the scan?
- certainly it should not depend on position X/Y;
- but also average value of reference λ disagree e.g. in Before and M1 sets.





Summary

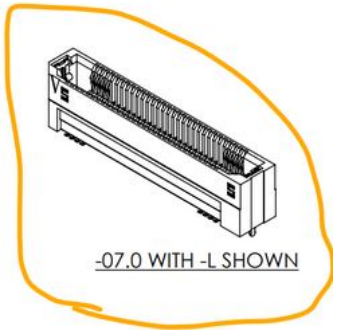
- Does it makes sense to takeλ=0.01 and λ=0.20 data? At λ=0.05 P(2)=0.00119, expected to give gain offset of 0.36% and sta.err.=0.6%.
- Moreover - change of laser intensity or change filters at every measurement makes λ unstable! Fixed laser intensity or no filter over entire ageing campaign would be more reliable.
- Add other 16 pads around measured region to preserve anode charge halo at the scan borders, MUST extend scan region to see not damaged borders;
- When Exit MCP is not used during ageing, the gain remains stable;
- Spot of >10 mm is too large or scan span too small, we don't see borders in H,V-scans.
- The gain recovered 10% in one month after ageing!
- MUST have the same REF measurements for ALL the settings, otherwise the normalizzation is not reliable (now we don't have H1 Before, H2 in M8, H2 and V2 in M8oct etc.).

Possible noise source

- readout board used ERF8 without latch option “-L”, coax ground disconnected from both sides of the cable.

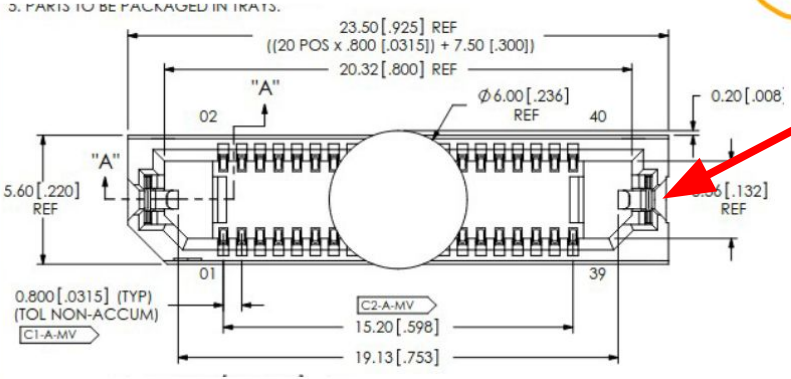
samtec

ERF8 sockets



Used for 32 pads

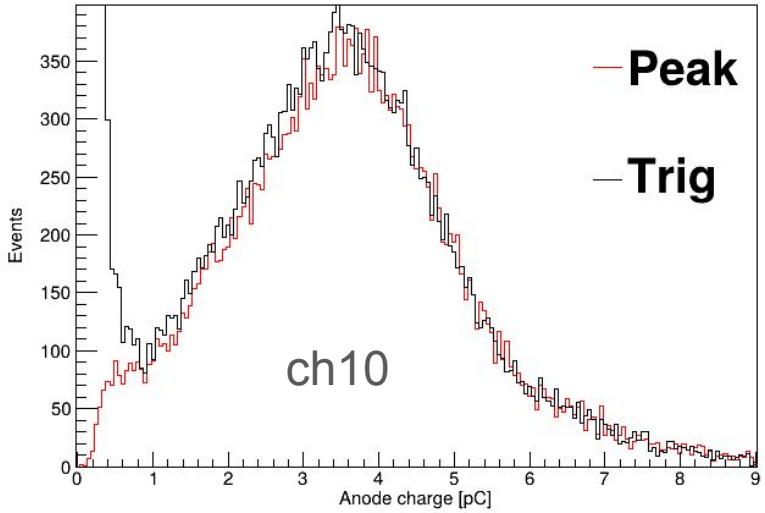
2 x 20 pins, 8 extras, 2 x 8 marked

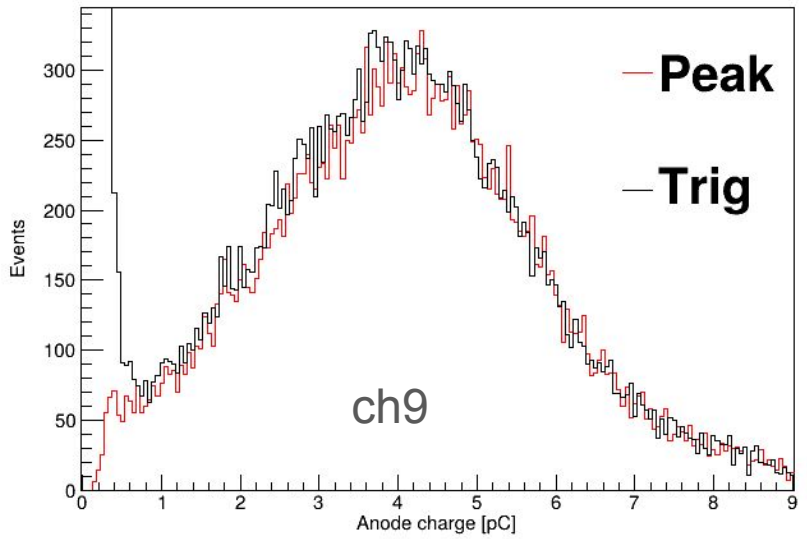


GND latches

Integration interval

- “Trig” - integral of all waveforms using integration interval determined from the trigger pulse in TR0;
- “Peak” - finds the signal peak first, and then integrate it within the same (fixed) integral gate, but adjusted to the observed peak position;
- peak integration allows to obtain signal spectrum also under the pedestal tail;
- agreement - means a good coincidence gate calibration.

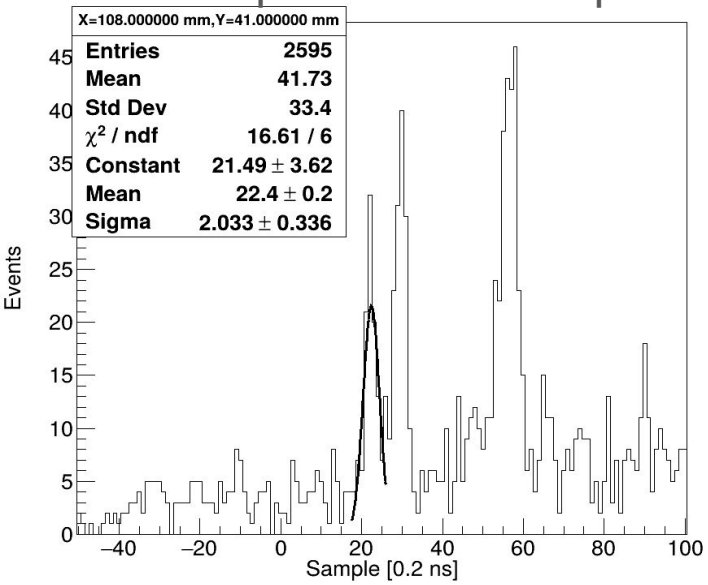




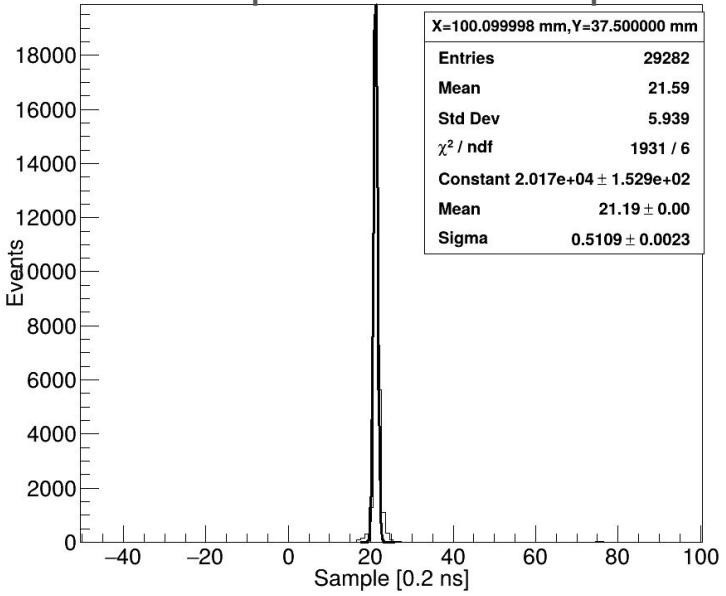
Coincidence gate calibration

- almost for all channels the coincidence (ch-TRn) occurs at 21.5 samples;
- coincidence gate inherited from MNP17 test: ±15 samples;
- but here, when laser spot is far from the channel we have other coincidence peaks: at ~30 samples and ~57 samples. And 30 samples peak enters in the coincidence gate! Should we apply smaller gate (±5 samples) to remove it?

laser spot far from the pad

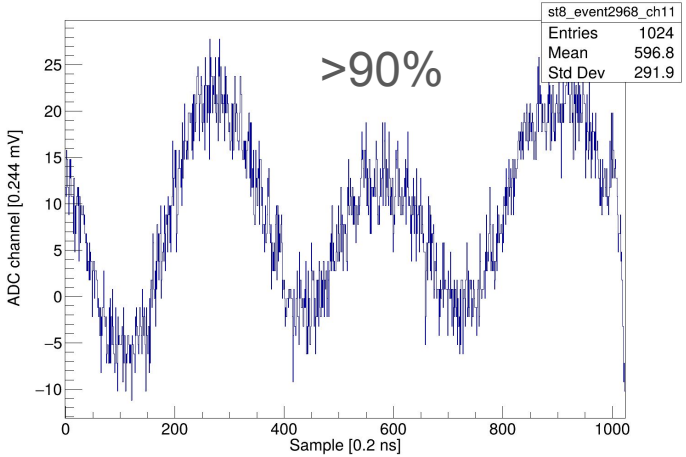


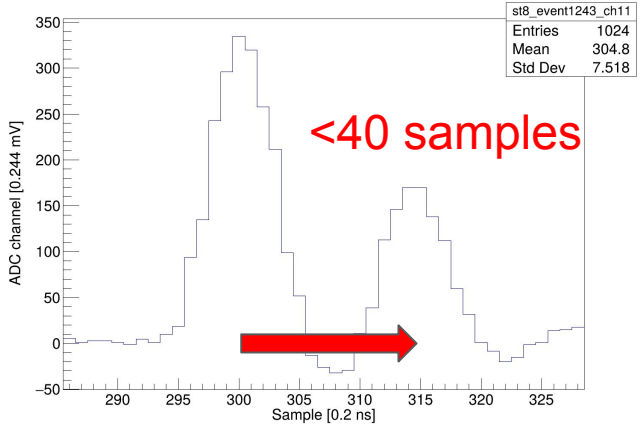
laser spot close to the pad



Missing and lost events

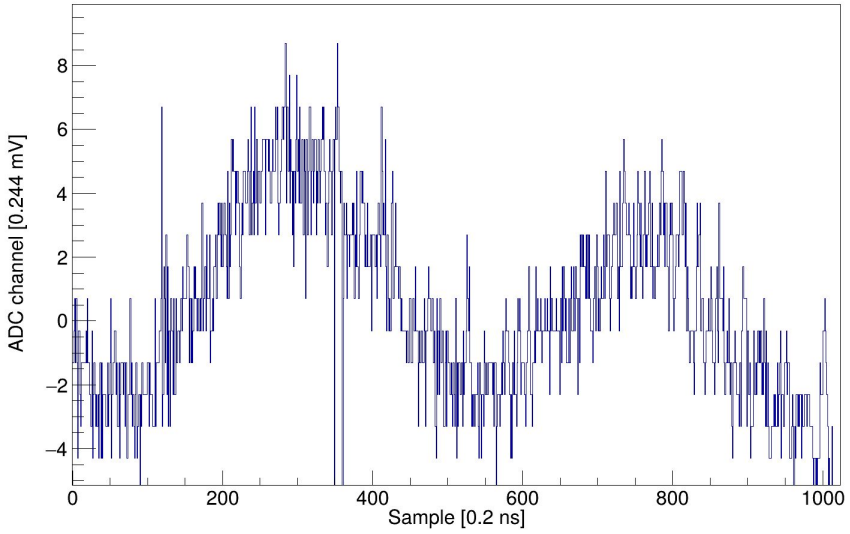
- code checks time interval between triggers, if it is >laser period it counts “missing events” - see the “Number of lost TRn trigger events” in the output:
  - presumably does not change λ;
- algorithm checks the presence of trigger in TR0, if it is not reconstructed entire event is lost - see “Lost evt” in the output:
  - presumably does not change λ;
- if baseline noise before signal >3*σ this channel is lost - see “Noise evt” in the output:
  - changes absolute value of λ - typically 5x10^{-4} of triggers and 0.2% of coincidences;
- if significant peaks or dips before or after signal - see the “EMI evt” in the output:
  - changes absolute value of λ - typically 2% of triggers.

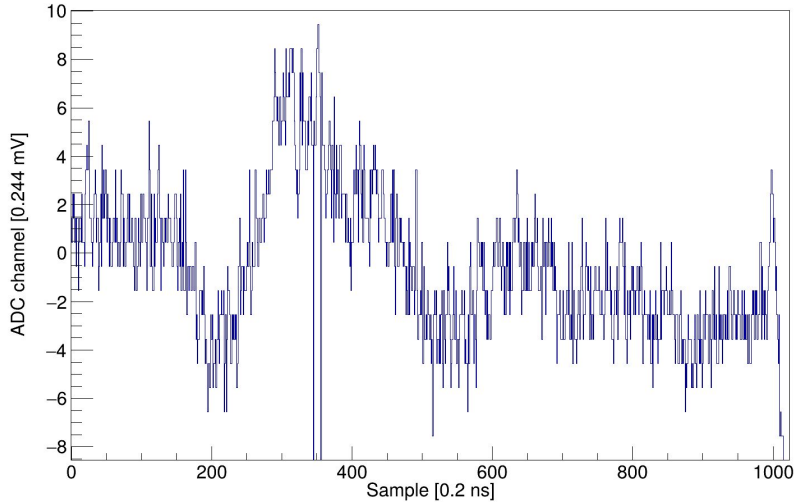




Noise issue

- noise RMS=1.7 lsb=0.415 mV, however HF-noise of amplitude up to 13 lsb=3.2 mV_{pp} is observed in the data, almost 10 times higher than baseline width;
- amplifiers do not help, amplifying HF-noise to 30 mV_{pp};
- source of HF-noise must be identified: try to turn OFF HRPPD bias and see if it is still present (weak ground connection?).





Anode charge in pads

- significant gain variations in some border pads;
- loss of charge when l.h.s. pad goes out of measured area;
- gain of charge when bottom pad goes out of measured area;
- in the central region pad-to-pad variations of peak charge from -9% to +5%.